

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
21 May 2004 (21.05.2004)

PCT

(10) International Publication Number
WO 2004/042320 A1

(51) International Patent Classification⁷: **G01B 11/00**,
H01S 5/00, 3/08

(21) International Application Number:
PCT/US2003/034445

(22) International Filing Date: 29 October 2003 (29.10.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/283,730 30 October 2002 (30.10.2002) US

(71) Applicant: **PHOTODIGM, INC.** [US/US]; John E.
Spencer, Ph.D., Suite 200, 1155 E. Collins Blvd., Richard-
son, TX 75081 (US).

(72) Inventor: **BHANDARKAR, Sarvotham**; 7101 Chase
Oaks Blvd., Apt. 1724, Plano, TX 75025 (US).

(74) Agent: **YEE, Duke**; Carstens, Yee & Cahoon, L.L.P., P.O.
Box 802334, Dallas, TX 75380 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,
CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE,
GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR,
KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK,
MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT,
RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR,
TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

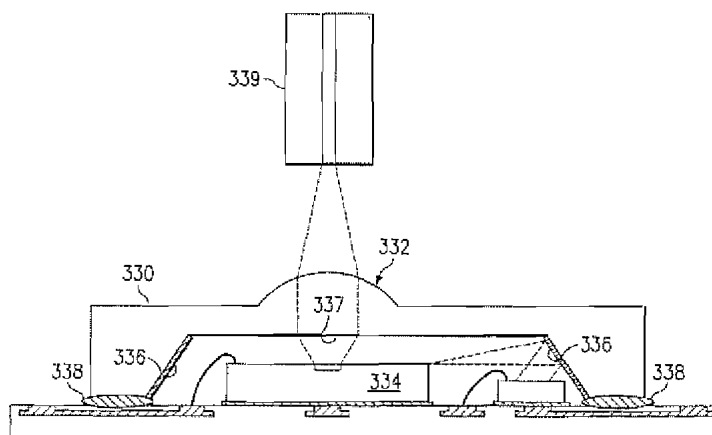
(84) Designated States (*regional*): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO,
SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM,
GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted
a patent (Rule 4.17(ii)) for the following designations AE,
AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH,
CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES,
FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,
KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,
MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH,

[Continued on next page]

(54) Title: PLANAR AND WAFER LEVEL PACKAGING OF SEMICONDUCTOR LASERS AND PHOTO DETECTORS FOR TRANSMITTER OPTICAL SUB-ASSEMBLIES



(57) Abstract: A planar wafer-level packaging method is provided for a laser and a monitor photo detector. The laser (310) and photo detector (320) are affixed to a planar substrate (302). The planar substrate (302) provides electrical connections to the components. A lens cap (330) with a microlens (332) is formed and affixed to the substrate (302) with a seal (338). The lens cap (330) forms a hermetically sealed cavity enclosing the laser (310) and photo detector (320). The inside surface of the lens cap (330) has a reflective coating (336) with a central opening over the emitting aperture of the laser (310). The central opening has an anti-reflective coating (337). Light from the laser (310) is directed and shaped by the lens cap (330) to couple into an external light guide (339). Residual light from the edge of the laser (310) reflects off the inside surface of the lens cap (330) and is incident upon the photo detector (320). In an alternate method, the laser (310) may be packaged using flip-chip assembly.



- PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

Published:

- *with international search report*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

PLANAR AND WAFER LEVEL PACKAGING OF SEMICONDUCTOR LASERS AND PHOTO DETECTORS FOR TRANSMITTER OPTICAL SUB-ASSEMBLIES

BACKGROUND OF THE INVENTION

5

1. Technical Field:

The present invention relates to lasers and, in particular, to packaging for laser assemblies. Still more particularly, the present invention provides a method and apparatus for packaging a laser and a monitor photo detector on a wafer level planar assembly.

10

2. Description of Related Art:

Fiber optics are used for short distance communications. A laser (Light Amplification by the Stimulated Emission of Radiation) is a device that creates a uniform and coherent light that is very different from an ordinary light bulb. Many lasers deliver light in an almost-perfectly parallel beam (collimated) that is very pure, approaching a single wavelength. Solid state lasers create ultra-high-speed, miniscule pulses traveling in optical fibers. Light traveling in an optical fiber is impervious to external interference, which is a problem with electrical pulses in copper wire.

15

An optical fiber is a thin glass strand designed for light transmission. A single hair-thin fiber is capable of transmitting trillions of bits per second. There are two primary types of fiber. Multimode fiber is very common for short distances and has a core diameter of from 50 to 100 microns. For intercity cabling and highest speed, singlemode fiber with a core diameter of less than 10 microns is used.

20

Two examples of solid-state lasers are the edge emitting laser and the vertical cavity surface emitting laser (VCSEL). VCSELs are fabricated in a chip and the laser is emitted from the surface of the chip. A VCSEL has a wavelength of about 850 nm. A VCSEL can only be used with multimode fibers. Therefore, VCSELs are limited in speed and distance. Edge emitting lasers are fabricated in a chip and the laser is emitted from the edge of the chip. An edge emitting laser has a wavelength between 1300 nm and 1550 nm. An edge emitting laser may be used with a singlemode fiber. However, edge emitting lasers present problems in packaging.

25

30

Figure 1 illustrates an example packaging of an edge emitting laser. The top edge of laser **110** has an anti-reflective (AR) coating while the bottom edge has a highly reflective (HR) coating. Light is generated and is emitted from the top edge, as shown in **Figure 1**. The light is directed through lens **120**. Residual light from the bottom edge of the laser is measured by photo detector **130**. Feedback from the photo detector may be used to control the laser.

As seen in **Figure 1**, the packaging of the edge emitting laser is a vertical packaging. This is a difficult process to implement because the laser must be aligned with the lens and the photo detector in a vertical orientation. Furthermore, due to the vertical orientation of an edge emitting laser, the process of aligning and packaging the laser cannot be fully automated. The manufacturer of the laser must either complete the assembly of the laser product or sell the laser chip itself. If a customer buys the laser chip without an assembly, the customer must then face the challenges of aligning, packaging, and testing the laser.

Therefore, it would be advantageous to provide a method and apparatus for packaging a laser in a planar orientation.

SUMMARY OF THE INVENTION

The present invention provides a planar wafer-level packaging method for a laser and a monitor photo detector. The laser and photo detector are affixed to a planar substrate. The planar substrate provides electrical connections to the components. A lens cap with a microlens is formed. The lens cap is affixed to the substrate with a seal, such as solder. The lens cap forms a hermetically sealed cavity enclosing the laser and photo detector. The inside surface of the lens cap has a reflective coating with a central opening over the emitting aperture of the laser. The central opening has an anti-reflective coating. Light from the laser is directed and shaped by the lens cap to couple into an external light guide. Residual light from the edge of the laser reflects off the inside surface of the lens cap and is incident upon the photo detector. A plurality of such assemblies, each comprising a laser, a photo detector and a lens cap may be assembled on a single planar substrate. Alternatively a plurality of lasers and photo detectors may be assembled on the planar substrate. Next, a single substrate containing a plurality of lens caps may be aligned and affixed onto the planar substrate to complete the assembly. As yet another variation, the laser and the photo detector could each be arrays instead of single devices in the above embodiments.

In an alternate method, the laser may be packaged using flip-chip assembly. A microlens may be formed on a first side of a substrate with conductive lines and pads on a second side. Anti-reflective coating is applied on both sides of the substrate. The laser is flip-chip attached to the substrate pads using solder bumps on the second side of the substrate. Light from the laser is directed and shaped by the microlens to couple into an external light guide. The photo detector is affixed to the substrate on the second side. A cap is formed and affixed to the bottom surface of the substrate with a seal, such as solder. The inside surface of the cap has a reflective coating. Residual light from the edge of the laser reflects off the inside surface of the cap and is incident on the photo detector. The cap forms a hermetically sealed cavity enclosing the laser and photo detector. A heat sink attach material may be applied between the laser and the cap. The flip-chip design may be scaled to include a plurality of lasers and photo detectors, and also to include arrays of lasers and photo detectors.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 illustrates an example packaging of an edge emitting laser;

Figures 2A and 2B are diagrams depicting a grating-outcoupled surface emitting laser in accordance with a preferred embodiment of the present invention;

10 **Figures 3A-3I** are diagrams illustrating packaging of a grating-outcoupled surface emitting laser in accordance with a preferred embodiment of the present invention;

Figures 4A-4D are diagrams illustrating flip-chip packaging of a grating-outcoupled surface emitting laser in accordance with a preferred embodiment of the present invention;

15 **Figures 5A-5B** are diagrams illustrating packaging of an edge emitting laser in accordance with a preferred embodiment of the present invention;

Figures 6A-6D are diagrams illustrating flip-chip packaging of an edge emitting laser in accordance with a preferred embodiment of the present invention;

Figure 7 is a flowchart illustrating a process for packaging a grating-outcoupled surface emitting laser in accordance with a preferred embodiment of the present invention;

20 **Figure 8** is a flowchart illustrating a process for packaging a surface emitting laser using a flip-chip technique in accordance with a preferred embodiment of the present invention; and

Figures 9A-9D are example laser assemblies incorporating the surface emitting laser packaging of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The description of the preferred embodiment of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention the practical application to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

With reference now to the figures and in particular with reference to **Figures 2A and 2B**, diagrams depicting a grating-outcoupled surface emitting (GSE) laser are shown in accordance with a preferred embodiment of the present invention. Further details for the GSE laser may be found in copending patent application 09/844,484 (Attorney Docket No. PDGM-4) to Evans et al., entitled "Grating Outcoupled Surface Emitting Lasers," filed on April 27, 2001, and herein incorporated by reference.

Figure 2A illustrates a top view of a GSE laser, which is an example of a surface emitting laser to be used in a preferred embodiment of the present invention. Laser **200** includes an outcoupling grating **204**, which is located at an outcoupling aperture. On either end of the laser are located distributed Bragg reflectors (DBR) **202** for providing feedback into the cavity.

Alternatively, cleaved facets may also be used instead of reflector gratings, possibly with highly reflective coatings applied to reflect the light. With either DBR reflectors or coated facets, the reflectivity of one or both ends can be varied to allow light to escape the cavity at that end.

Figure 2B illustrates a side view of the GSE laser shown in **Figure 2A**. Laser **200** includes aperture **252** through which light is emitted. In a preferred embodiment, the outcoupled light **254** is emitted normal to the surface, since one primary goal is to couple this light into a light guide such as an optical fiber. The DBR reflectors or coated facts also allow residual light **256** to escape from the edge. Residual light **256** may be measured by a photo detector to provide feedback for controlling the laser.

With reference now to **Figures 3A-3I**, diagrams illustrating planar packaging of a surface emitting laser are shown in accordance with a preferred embodiment of the present invention. As shown in **Figure 3A**, substrate **302** is formed with conductive lines and pads **304**. The conductive lines and pads provide conductive channels from inside the packaging assembly to outside the packaging assembly beneath the surface of the substrate. Substrate **302** may be a semiconductor

material, such as silicon.

Next, as shown in **Figure 3B**, laser **310** is attached to the substrate at a pad location. Conductive wire **312** couples laser **310** to a second pad. Monitor photodiode **320** is attached to the substrate at a third pad location. Conductive wire **322** couples photodiode **320** to a fourth pad. In
5 an alternative embodiment of the present invention, a photo detector, such as photodiode **320**, may be integrated into laser **310**. However, for illustration in **Figures 3A-3I**, the photodiode is shown as a separate element.

Turning next to **Figure 3C**, lens cap **330** is formed with lens **332** and recess **334**. Lens cap **330** is formed using known molding or semiconductor processing techniques. Whereas a variety of
10 substrates and processing techniques may be used, in a preferred embodiment the lens cap may be formed on a silicon substrate using known grayscale masking techniques to form the lens, combined with bulk anisotropic etching of silicon to form the recess. The inside surface of the lens cap is coated with a reflective coating **336**. Reflective coating **336** has a central opening over the laser aperture. The central opening may have an anti-reflective coating **337**. Lens cap **330** is
15 attached to the substrate with a seal **338**, such as solder. Recess **334** forms a hermetically sealed cavity that completely encloses the laser and photo detector. The conductive lines **304** now provide electrical connections from a portion of the substrate inside the cavity to a portion of the substrate outside the cavity. Light from the surface of the laser is directed and shaped by the lens cap to couple into an external light guide **339**. Residual light from the edge of the laser reflects off the
20 inside inclined walls of the lens cap and is incident on the surface of the photo detector **320**.

With reference now to **Figure 3D-3E**, diagrams illustrating a plurality of packages on the substrate are shown. As shown in **Figure 3D**, a plurality of packages may be constructed on a single substrate **340** each comprising a laser **342**, a photo detector **344** and a lens cap **346**. **Figure 3E** shows another variation in which a plurality of lasers **352** and photo detectors **354** are
25 assembled on a first substrate **350**. Next a second substrate **358** comprising a plurality of lens caps **356** may be affixed onto the first substrate to complete the assembly. As yet another variation, the laser and the photo detector could each be arrays instead of single devices, with the array running into the plane of the paper in **Figure 3A-E**.

The planar packaging depicted in **Figures 3A-3E** therefore provides a self-contained
30 package for a surface emitting laser that: a) directs and shapes the light from the laser for the purpose of coupling into an external light guide; b) couples light from the laser into the monitor photo detector; c) provides electrical connections to the laser and photo detector; d) provides protection for the laser and photo detector from the environment. In other words, the planar wafer

level package performs all the critical functions of a conventional package.

With reference now to **Figures 3F-3G**, diagrams illustrating alternate methods of coupling light from the edge of the laser into the photo detector are depicted. As shown in **Figure 3F**, residual light from the edge of laser **362** is directly coupled into photo detector **364** without the need to reflect off of lens cap **368**. In another embodiment, **Figure 3G**, a portion **376** of lens cap **378** may be coated with a partial reflective coating. A fraction of the light emitted from the surface of laser **372** reflects off of surface **376** and is incident onto photo detector **374**.

Next as shown in **Figure 3H-3I**, the lens cap may be formed in many ways, two preferred embodiments being shown. **Figure 3H** shows the lens cap **380** to be formed from two separate elements, an upper half **384** and a lower half **382** being bonded together. **Figure 3I** shows an embodiment of a lens cap **390** with multiple lens elements **392** and **394**.

With reference now to **Figures 4A-4C**, diagrams illustrating flip-chip packaging of a surface emitting laser are shown in accordance with a preferred embodiment of the present invention. As shown in **Figure 4A**, substrate **402** is formed with conductive lines and pads **404** on a bottom surface and etched with lens **406** on a top surface. The conductive lines and pads provide conductive channels from inside the packaging assembly to outside the packaging assembly beneath the surface of the substrate. Substrate **402** may be, but is not limited to, a semiconductor material, such as silicon. Conductive lines and pads **404** and lens **406** may be formed by using known semiconductor processing techniques. The lens may be formed using known molding techniques or semiconductor processing techniques. More particularly, the lens may be formed using a grayscale masking technique.

Next, as shown in **Figure 4B**, laser **410** is attached to the substrate at pad locations by attaching the laser by solder bumps **412**. Monitor photodiode **420** is attached to the substrate at a third pad location. Conductive wire **422** couples photodiode **420** to a fourth pad location.

Turning next to **Figure 4C**, cap **430** is formed having recess **434**. Cap **430** is formed using known molding or semiconductor processing techniques. The inside surface of the cap is coated with reflective surface **436**. Cap **430** is attached to the substrate with a seal **432**, such as solder. Recess **434** forms a hermetically sealed cavity that completely encloses the laser and the photo detector. Heatsink attach material **438** may be applied between the laser and cap **430**. Light from the surface of the laser is directed and shaped by the lens to couple into an external light guide **439**. Residual light from the edge of the laser reflects off the inside inclined walls of the cap and is incident on the surface of the photo detector **420**.

With reference now to **Figure 4D**, a diagram illustrating an alternate method of coupling

light from the edge of the laser into the photo detector is depicted wherein residual light from the edge of laser 442 is directly coupled into photo detector 444 without the need to reflect off of cap 448.

Similar to the planar packaging depicted in **Figures 3D-3E**, the planar packaging shown in **Figures 4A-4D** provides a self-contained package for a surface emitting laser and is easily scalable to include a plurality of individual lasers and photo detectors on a substrate as well as to arrays of lasers and photo detectors.

Whereas the embodiments described thus far are applicable to grating outcoupled surface emitters and conventional surface emitters (VCSELs), the following embodiments described in **Figures 5A-5B** and **Figures 6A-6D** are applicable to edge emitters. As shown in **Figure 5A**, substrate 500 is hermetically bonded to interposer 501 which has on its internal walls a reflective coating 505. Edge emitter 503 and photo detector 504 are affixed on substrate 500. Next, lens cap 502 is affixed onto interposer 501. A portion of the bottom surface of lens cap 502 has applied thereon a reflective coating 506. Light from the edge of the laser 503 reflects off one reflective wall 505 and is directed and shaped by lens 507 into light guide 508. Residual light from the other edge of laser 503 reflects off surfaces 505 and 506 and is incident on the photo detector 504. **Figure 5B** shows an embodiment similar to that of **Figure 5A**, but with the residual light from the edge of the laser 522 being directly coupled into photo detector 524.

With reference now to **Figures 6A-6D**, diagrams illustrating alternate packaging of edge emitting laser are shown. As shown in **Figure 6A**, substrate 600 is formed with conductive lines and pads on a bottom surface and etched with lens 607 on a top surface. Next, laser 603 and monitor photodiode 604 are attached to substrate 600. Cap 602 is formed with a reflective coating 605 applied on the inside surface. Cap 602 is affixed to substrate 600 with a hermetic seal. Light from the edge of the laser 603 reflects off of reflective wall 605 and is directed and shaped by lens 607 into light guide 608. Residual light from edge of laser 603 reflects off of reflective coating 605 and is incident on photo detector 604. **Figure 6B** shows an embodiment similar to that of **Figure 6A**, but with the residual light from the edge of the laser 612 being directly coupled into photo detector 614. **Figure 6C**, shows an embodiment similar to **Figure 6A**, but with laser 633 affixed to substrate 630 with solder bumps 639. Additionally substrate 630 has a precision standoff 636 that maintains the laser surface at a fixed height from substrate 630. Heatsink attach material 631 may be applied between laser 633 and cap 632. **Figure 6D** shows another embodiment similar to that in **Figure 6C**, but with photo detector 644 receiving residual light directly from laser 643.

With reference now to **Figure 7**, a flowchart illustrating a process for packaging a surface emitting laser is shown in accordance with a preferred embodiment of the present invention. The process begins and conductive lines and pads are deposited into a substrate (step 702). Next, monitor photodiode is attached to the substrate at a pad location (step 704) and the photodiode is electrically coupled to another pad (step 706). Thereafter, the laser is attached to the substrate at a pad location (step 708) and the laser is electrically coupled to another pad (step 710). Then, a silicon lens cap is attached over the laser and the monitor photodiode with a hermetic seal (step 712) and the process ends.

Turning now to **Figure 8**, a flowchart illustrating a process for packaging a surface emitting laser using a flip-chip technique is shown in accordance with a preferred embodiment of the present invention. The process begins and conductive lines and pads are deposited into a microlens substrate (step 802). Next, monitor photodiode is attached to the substrate at a pad location (step 804) and the photodiode is electrically coupled to another pad (step 806). Thereafter, the laser is attached to the microlens substrate with solder bumps at two pad locations (step 808). Then, a silicon cap is attached over the laser and the monitor photodiode with a hermetic seal (step 810) and the process ends.

The packaging format described above is advantageous in many ways. One significant advantage is that the planar format lends itself to automated assembly using commercial pick and place equipment available in the semiconductor industry. In particular, the optical axis of the lens can be passively aligned to the optical axis of the laser beam using fiducial marks on the laser and lens cap, with commercial precision pick and place equipment. More particularly, sub-micron alignment precisions, required for improved coupling efficiency into singlemode light guides, can be achieved for example by using eutectic die attach and in-situ reflow on precision die attach equipment. Self-alignment forces of solder reflow may also be used as an alignment mechanism for the flip-chip method. The above methods allow for complete automation and provide much faster assembly times than the tedious active align processes used in conventional packaging.

Furthermore, multiple laser packages may be fabricated on a single substrate wafer further improving assembly throughputs by reducing handling and indexing times. Another key advantage is that the substrate wafer may be bussed on the saw streets to simultaneously energize all packages on the wafer. This enables efficient wafer-level testing and burn-in after which the packages are singulated by dicing the saw streets. The package is hermetically sealed; therefore, it can be incorporated into a laser assembly by the customer without the extra effort of aligning the lens, aligning the photo detector, and hermetically sealing the assembly. The planar package also has a

much smaller vertical profile and a smaller footprint than a conventional laser assembly. Another key advantage is that the use of a silicon substrate enables the integration of drive electronics on the substrate which then becomes an enabler for high speed modulation of the laser.

With reference now to **Figures 9A-9D**, example laser assemblies are shown incorporating the surface emitting laser packaging of the present invention. **Figure 9A** illustrates a transmitter optical sub assembly (TOSA). Laser package **902** is provided in the TOSA with current being provided by leads **904**. The TOSA also has fiber **906** coupled and aligned to the laser.

Figure 9B illustrates a lead frame package incorporating the planar packaged surface emitting laser of the present invention. The lead frame package incorporates laser package **912** into an assembly that provides external leads **914**. **Figure 9C** depicts a flex tape assembly. Laser package **922** is coupled to flexible tape **924**. Electrical connections are provided through conductive lines within tape **924**. **Figure 9D** shows a chip-on-board assembly. Laser package **932** may be attached directly to printed circuit board (PCB) **934**. Electrical connections may be made from the laser package to the circuit board, making the communications between circuitry on the PCB and the laser package more efficient.

Thus, the present invention solves the disadvantages of the prior art by providing planar packaging for lasers. The alignment and assembly of components in the package is accomplished in a passive manner and therefore may be virtually fully automated using machine vision.

Therefore, the packages may be manufactured at a higher volume more reliably and at a lower cost.

The use of a silicon substrate enables the integration of drive electronics close to the laser thereby enabling high modulation speeds. The compact planar package has equal or better coupling efficiency. Furthermore, the package is hermetic at the substrate wafer level, thus enabling wafer-level testing and burn-in. Many laser packages may be fabricated on a substrate wafer and testing and burn-in may be performed on all packages on the substrate wafer at one time. Also, a key advantage of this is that subsequent assemblies or packages, such as precision molded TOSA or small outline integrated circuit (SOIC) may be non-hermetic. The planar package of the present invention provides a standard subassembly or subpackage, thus simplifying assembly, testing, burn-in, etc. The subassembly of the present invention may be simply dropped into a customer-specific package in one final assembly step, saving the customer the additional steps of performing tedious alignment, sealing, testing, and burn-in tasks.

CLAIMS

What is claimed is:

1. A method for packaging a surface emitting laser, the method comprising:
5 attaching a laser to a first substrate, wherein the laser emits a laser beam from a surface of the laser;
attaching a photo detector to the first substrate, wherein the photo detector receives light from the laser; and
attaching a second substrate to the first substrate, wherein the first substrate and the
10 second substrate enclose the laser and the photo detector in a cavity,
wherein one of the first substrate and the second substrate includes at least one lens element, and
wherein the at least one lens element is constructed and positioned with respect to the laser to shape and direct the laser beam into a light guide.
15
2. The method of claim 1, wherein the step of attaching the photo detector to the substrate includes aligning the photo detector so that the photo detector receives light from an edge of the laser.
- 20 3. The method of claim 2, wherein the step of aligning the photo detector includes aligning the photo detector so that the photo detector receives light directly from the edge of the laser.
4. The method of claim 2, wherein the step of aligning the photo detector includes aligning the photo detector so that the photo detector receives light from the edge of the laser via
25 reflection from an inside surface of the second substrate.
5. The method of claim 1, wherein the photo detector is integrated into the laser.
6. The method of claim 1, wherein the step of attaching the second substrate to the first
30 substrate includes affixing the second substrate to the first substrate with a hermetic seal.
7. The method of claim 1, wherein the first substrate provides electrical connections from a portion of the first substrate inside the cavity to a portion of the first substrate outside the cavity.

8. A method for packaging a surface emitting laser, the method comprising:
attaching a laser to a first substrate, wherein the laser emits a laser beam from a first edge
of the laser;

5 attaching a photo detector to the first substrate, wherein the photo detector receives light
from the laser;

attaching an interposer to the first substrate; and

attaching a second substrate to the interposer, wherein the first substrate, the interposer,
and the second substrate enclose the laser and the photo detector in a cavity,

10 wherein one of the first substrate and the second substrate includes at least one lens
element, and

wherein the at least one lens element is constructed and positioned with respect to the
laser to receive the laser beam from the first edge of the laser via reflection from an inside
surface of the interposer and to shape and direct the laser beam into a light guide.

15 9. The method of claim 8, wherein the step of attaching the photo detector to the first
substrate includes aligning the photo detector so that the photo detector receives light from a
second edge of the laser.

20 10. The method of claim 9, wherein the step of aligning the photo detector includes aligning
the photo detector so that the photo detector receives light directly from the second edge of the
laser.

25 11. The method of claim 9, wherein the step of aligning the photo detector includes aligning
the photo detector so that the photo detector receives light from the second edge of the laser via
reflection from an inside surface of the interposer.

12. The method of claim 8, wherein the photo detector is integrated into the laser.

30 13. The method of claim 8, wherein the first substrate provides electrical connections from a
portion of the first substrate inside the cavity to a portion of the first substrate outside the cavity.

14. A laser assembly, comprising:

a first substrate;

a second substrate; and

a laser attached to the second substrate, wherein the laser emits a laser beam,

5 wherein one of the first substrate and the second substrate has formed therein a lens element,

wherein the first substrate and the second substrate form a sealed cavity enclosing the laser, and

wherein the lens element directs and shapes the laser beam into a light guide.

10

15. The laser assembly of claim 14, wherein laser emits the laser beam through an aperture on a surface of the laser.

16. The laser assembly of claim 15, wherein the first substrate has formed therein the lens

15 element on a top surface.

17. The laser assembly of claim 16, further comprising a photo detector attached to the second substrate, wherein the photo detector receives light from the laser.

20 18. The laser assembly of claim 17, wherein the photo detector is enclosed within the cavity.

19. The laser assembly of claim 17, wherein the first substrate has a reflective coating on a bottom surface.

25 20. The laser assembly of claim 19, wherein the photo detector receives light from an edge of the laser via reflection from the reflective coating.

21. The laser assembly of claim 19, wherein the reflective coating has an anti-reflective opening over the aperture.

30

22. The laser assembly of claim 17, wherein the first substrate has a partially reflective coating over the aperture and wherein the photo detector receives light from the surface of the laser via partial reflection of the laser beam.

23. The laser assembly of claim 17, wherein the photo detector receives light directly from an edge of the laser.

5 24. The laser assembly of claim 16, wherein the lens element is positioned above the aperture.

25. The laser assembly of claim 15, wherein the second substrate has formed therein the lens element on a top surface.

10

26. The laser assembly of claim 25, wherein the laser is attached to the second substrate on a bottom surface.

15

27. The laser assembly of claim 26, wherein a heatsink attach material is applied between the laser and the first substrate.

28. The laser assembly of claim 26, wherein the laser is attached using flip-chip.

20

29. The laser assembly of claim 26, further comprising a photo detector attached to the second substrate, wherein the photo detector receives light from the laser.

30. The laser assembly of claim 29, wherein the photo detector is enclosed within the cavity.

25

31. The laser assembly of claim 29, wherein the first substrate has a reflective coating on a top surface.

32. The laser assembly of claim 31, wherein the photo detector receives light from an edge of the laser via reflection from the reflective coating.

30

33. The laser assembly of claim 29, wherein the photo detector receives light directly from an edge of the laser.

34. The laser assembly of claim 14, wherein laser emits the laser beam through an edge of the laser.

5 35. The laser assembly of claim 34, wherein the first substrate has formed therein the lens element and wherein the lens element is positioned with respect to the laser to receive the laser beam from the edge of the laser via reflection from an inside surface of the first substrate and to shape and direct the laser beam into a light guide.

10 36. The laser assembly of claim 34, wherein the first substrate includes an interposer and wherein the interposer is attached to the second substrate to form the sealed cavity.

37. The laser assembly of claim 36, wherein the first substrate has formed therein the lens element and wherein the lens element is positioned with respect to the laser to receive the laser
15 beam from the edge of the laser via reflection from an inside surface of the interposer and to shape and direct the laser beam into a light guide.

38. The laser assembly of claim 34, wherein the second substrate has formed therein the lens element and wherein the lens element is positioned with respect to the laser to receive the laser
20 beam from the edge of the laser via reflection from an inside surface of the first substrate and to shape and direct the laser beam into a light guide.

39. The laser assembly of claim 14, wherein the second substrate provides electrical connections from a portion of the second substrate inside the sealed cavity to a portion of the
25 second substrate outside the sealed cavity.

40. A laser assembly, comprising:
a substrate;
a laser attached to the substrate, wherein the laser emits at least one laser beam from a
30 surface of the laser;
a photo detector attached to the substrate, wherein the photo detector receives light from an edge of the laser; and

a lens cap attached to the substrate, wherein the lens cap includes at least one lens element and wherein the substrate and the lens cap form a sealed cavity enclosing the laser and the photo detector,

5 wherein substrate provides electrical connections from a portion of the substrate inside the sealed cavity to a portion of the substrate outside the sealed cavity, and

wherein the at least one lens element is constructed and positioned with respect to the laser to shape and direct the at least one laser beam into at least one light guide.

41. A laser assembly, comprising:

10 a substrate;

a laser attached to a bottom surface of the substrate, wherein the laser emits at least one laser beam from a surface of the laser;

a photo detector attached to the bottom surface of the substrate, wherein the photo detector receives light from an edge of the laser; and

15 a cap attached to the substrate, wherein the substrate and the cap form a sealed cavity enclosing the laser and the photo detector,

wherein the substrate includes at least one lens element on a top surface of the substrate,

wherein substrate provides electrical connections from a portion of the substrate inside the sealed cavity to a portion of the substrate outside the sealed cavity, and

20 wherein the at least one lens element is constructed and positioned with respect to the laser to shape and direct the at least one laser beam into at least one light guide.

1/12

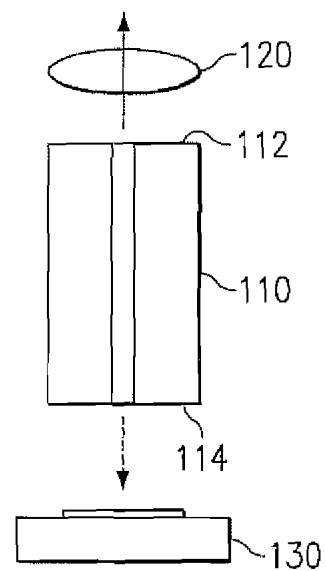


FIG. 1
(PRIOR ART)

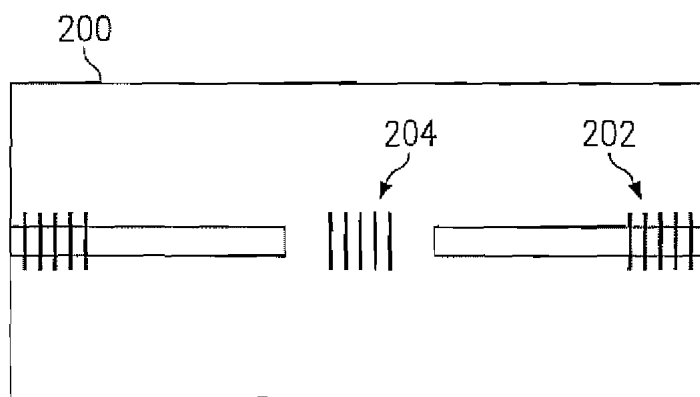


FIG. 2A

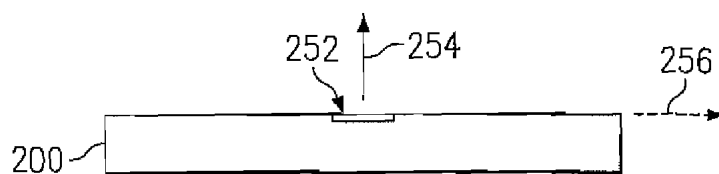
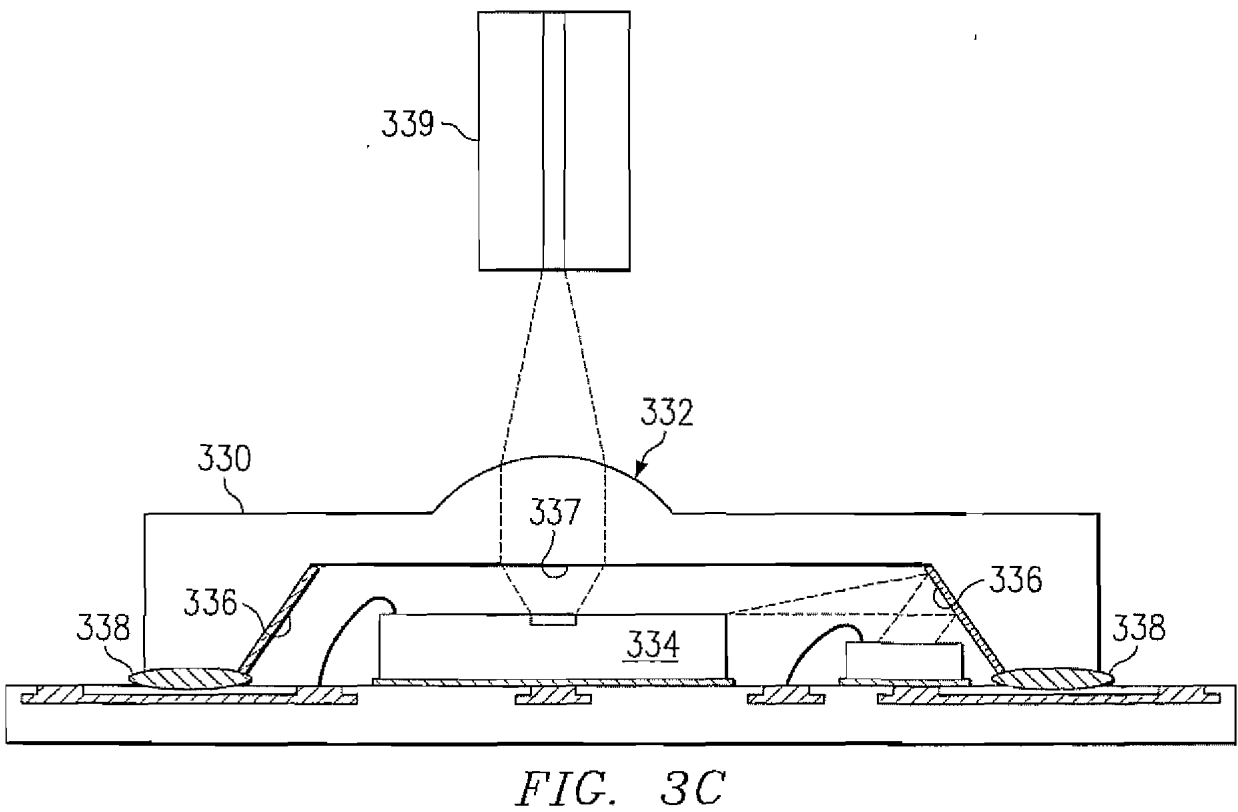
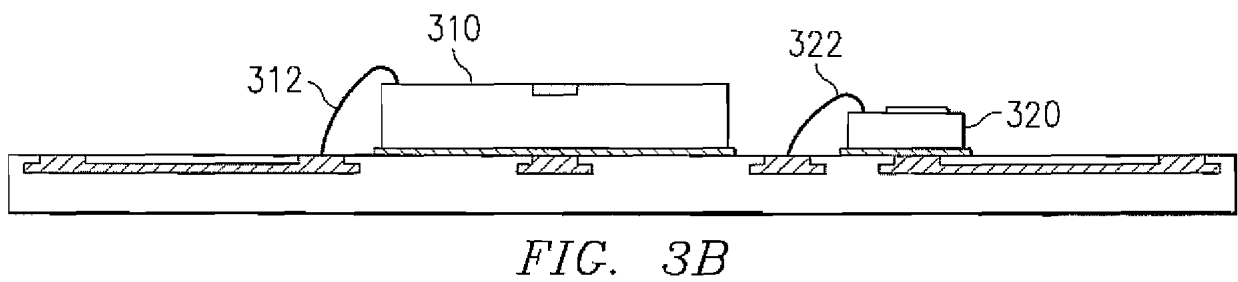
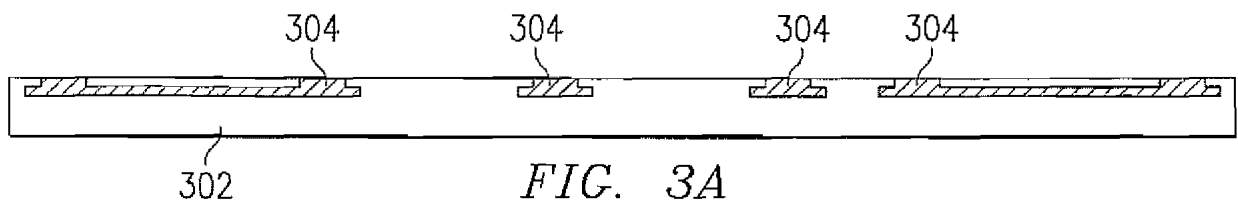
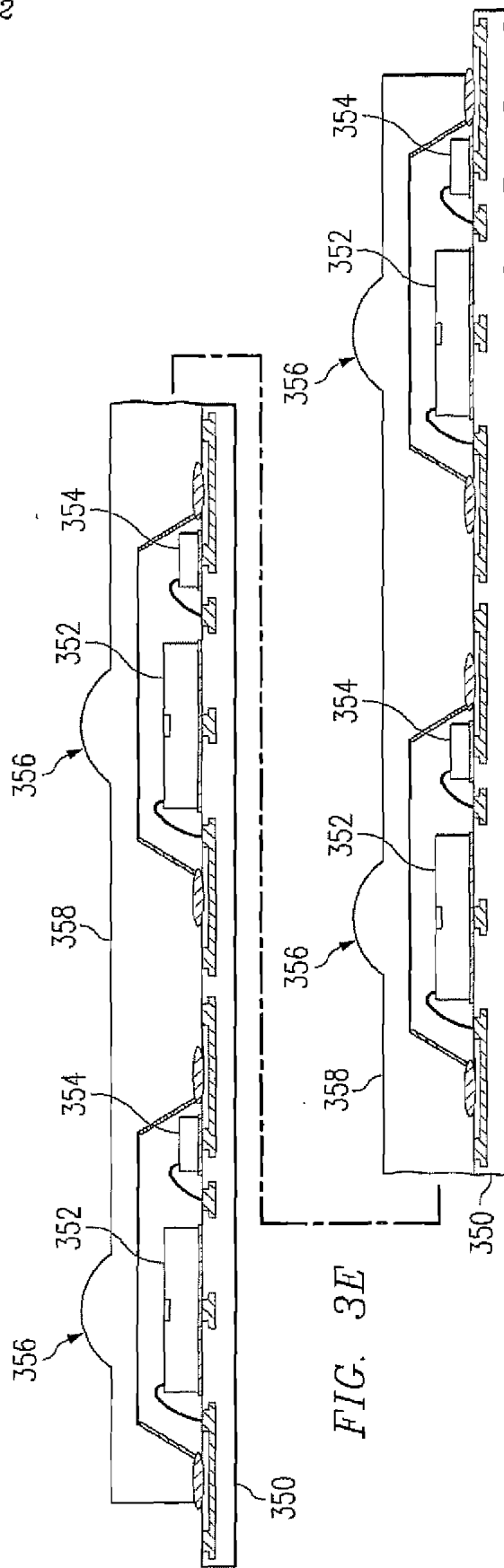
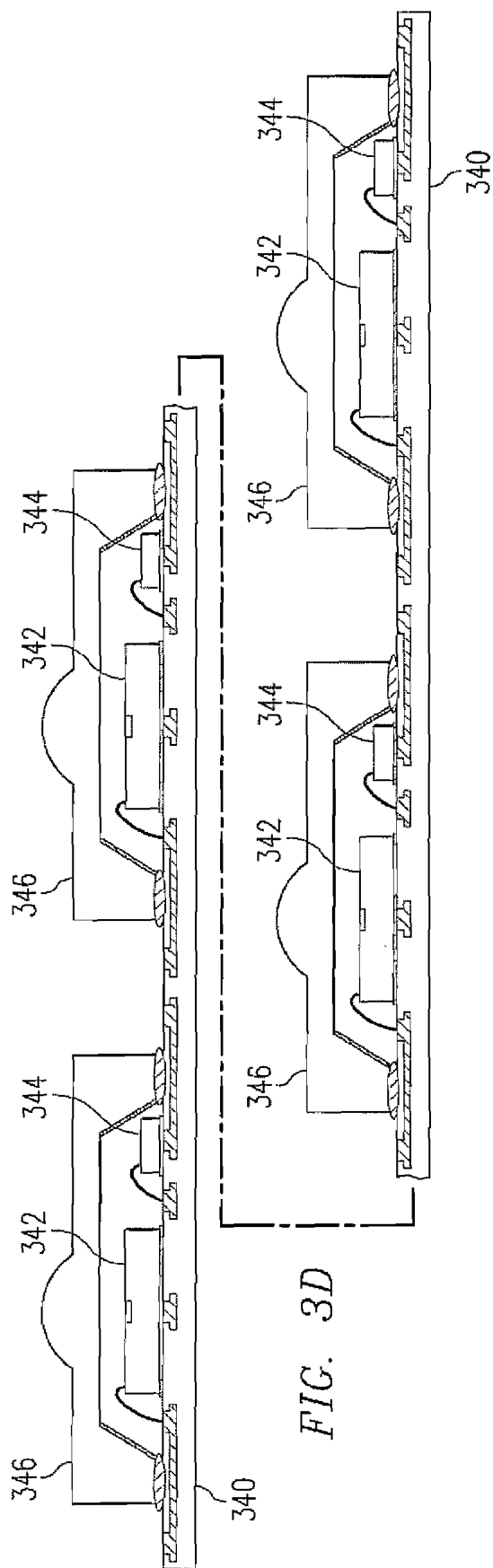


FIG. 2B

2/12



3/12



4/12

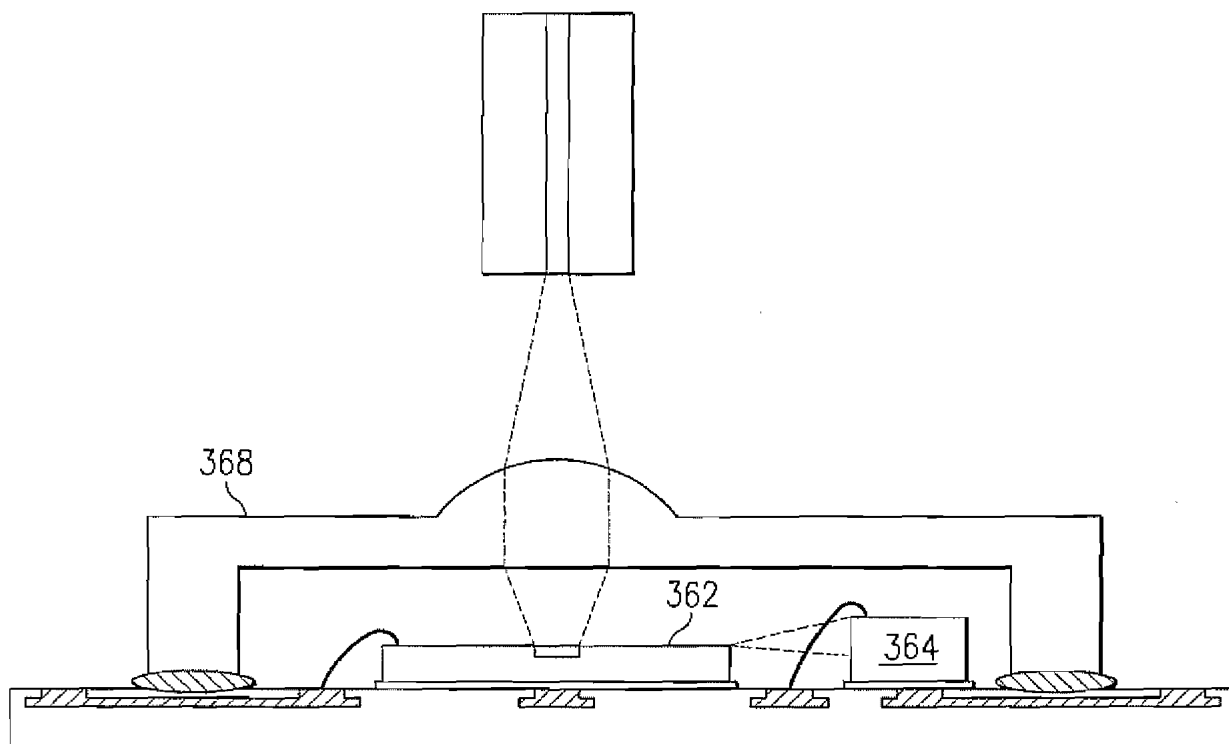


FIG. 3F

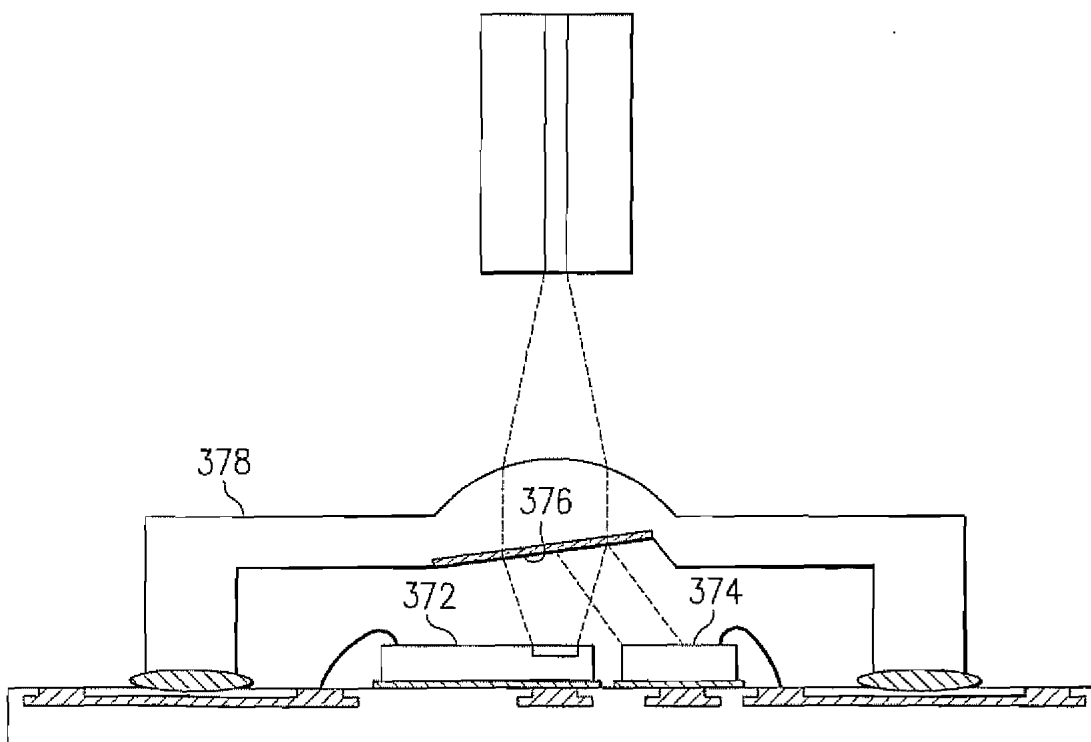


FIG. 3G

5/12

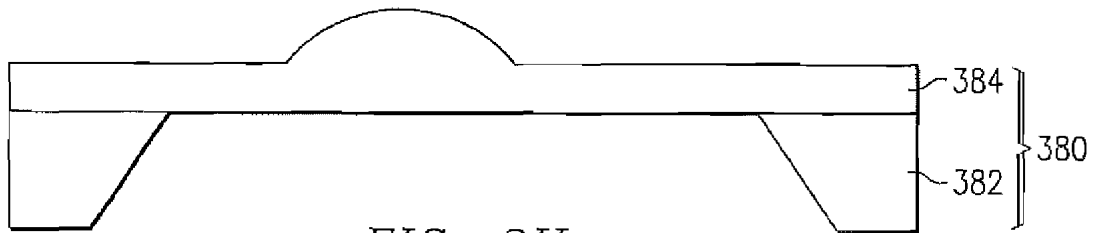


FIG. 3H

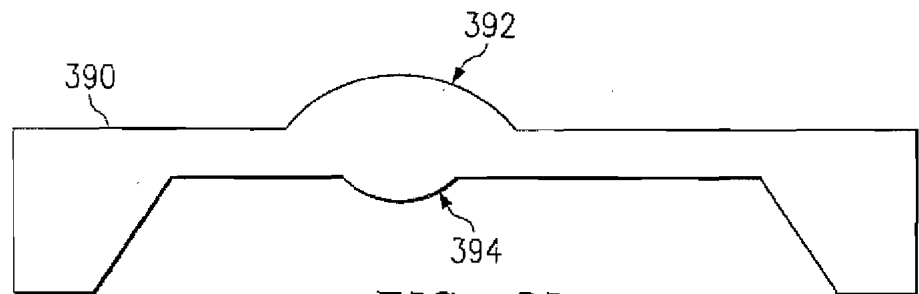


FIG. 3I

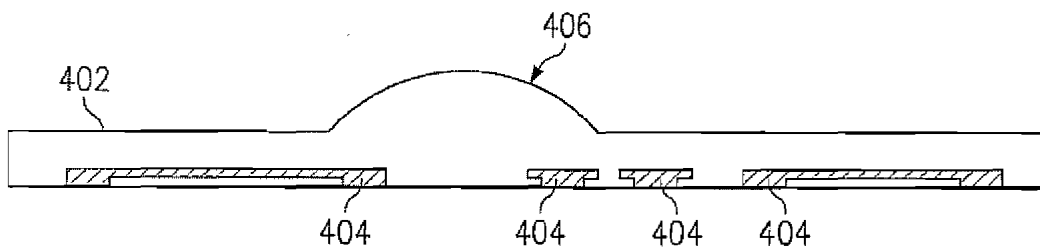


FIG. 4A

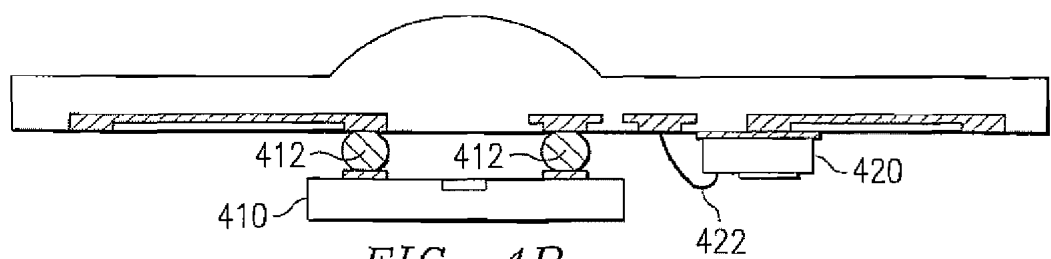
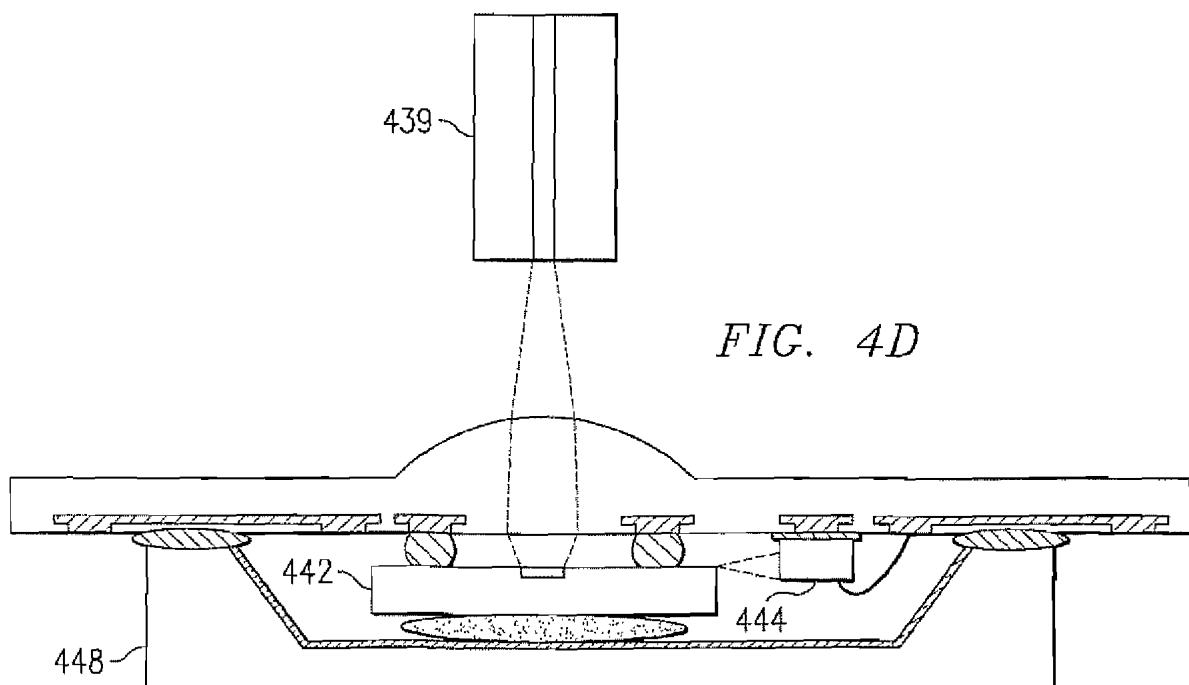
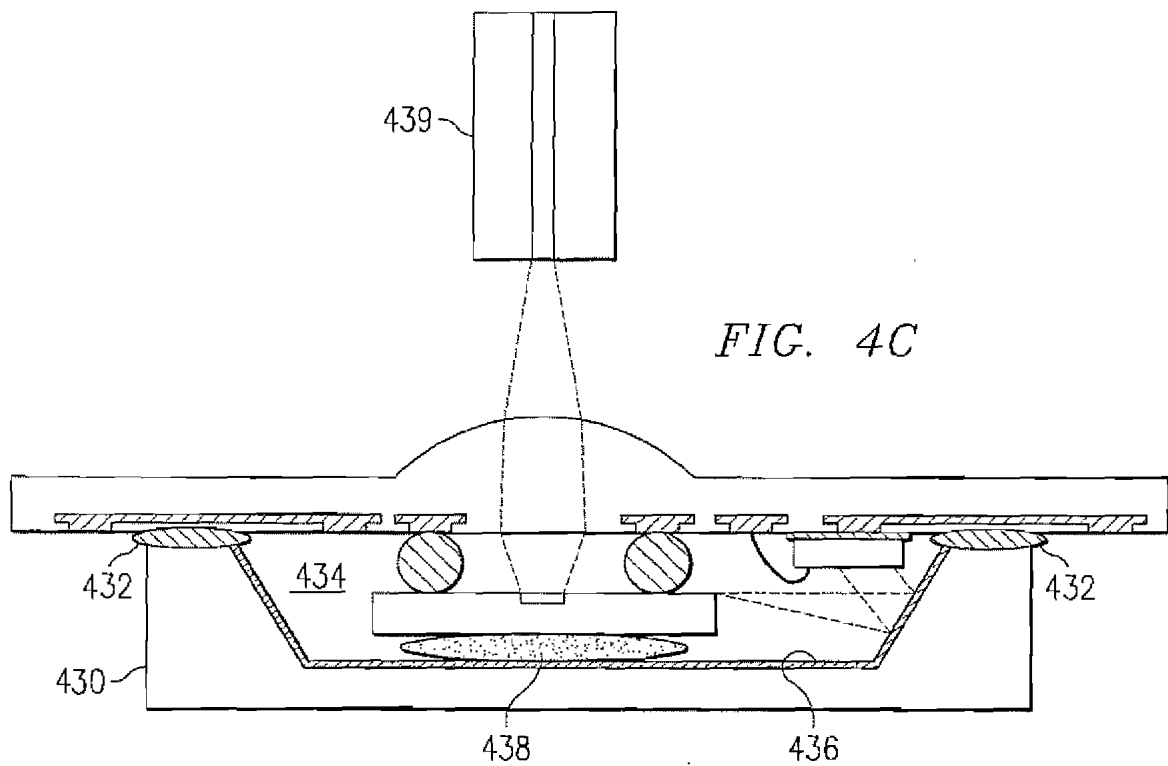
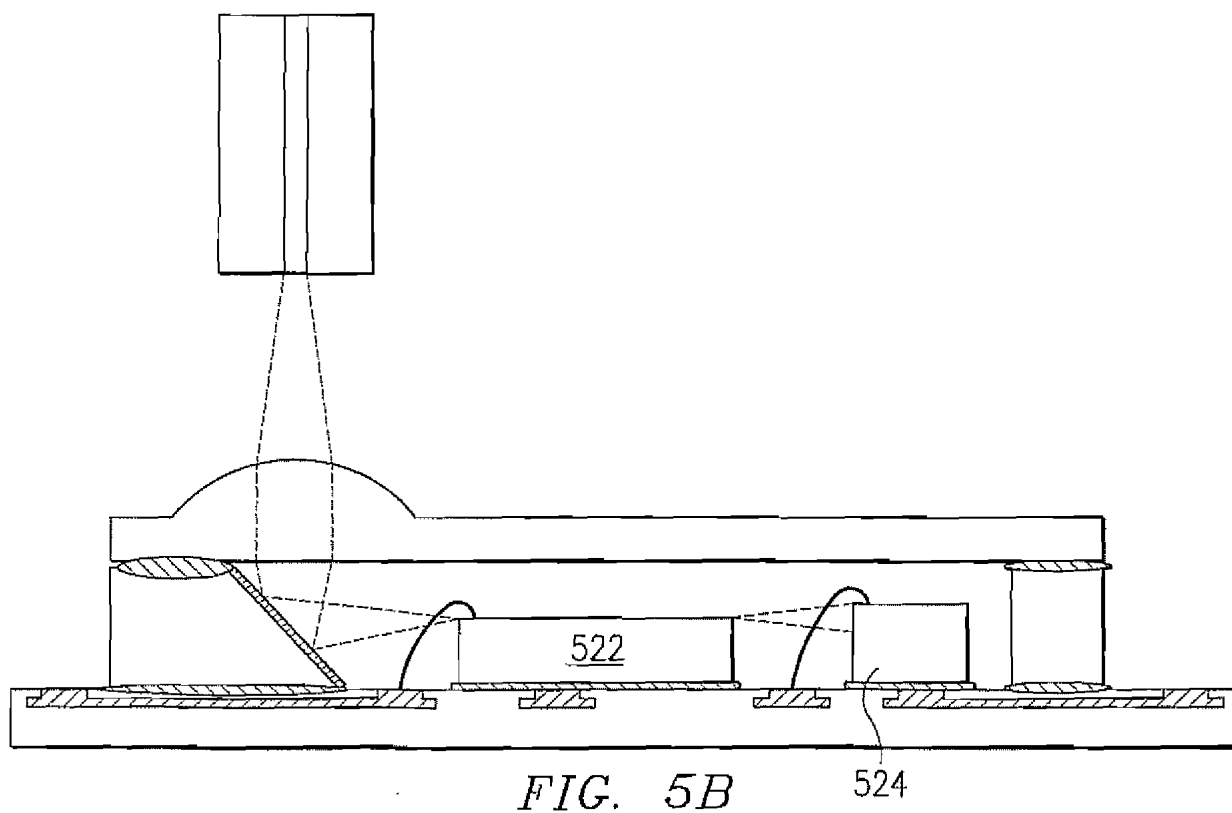
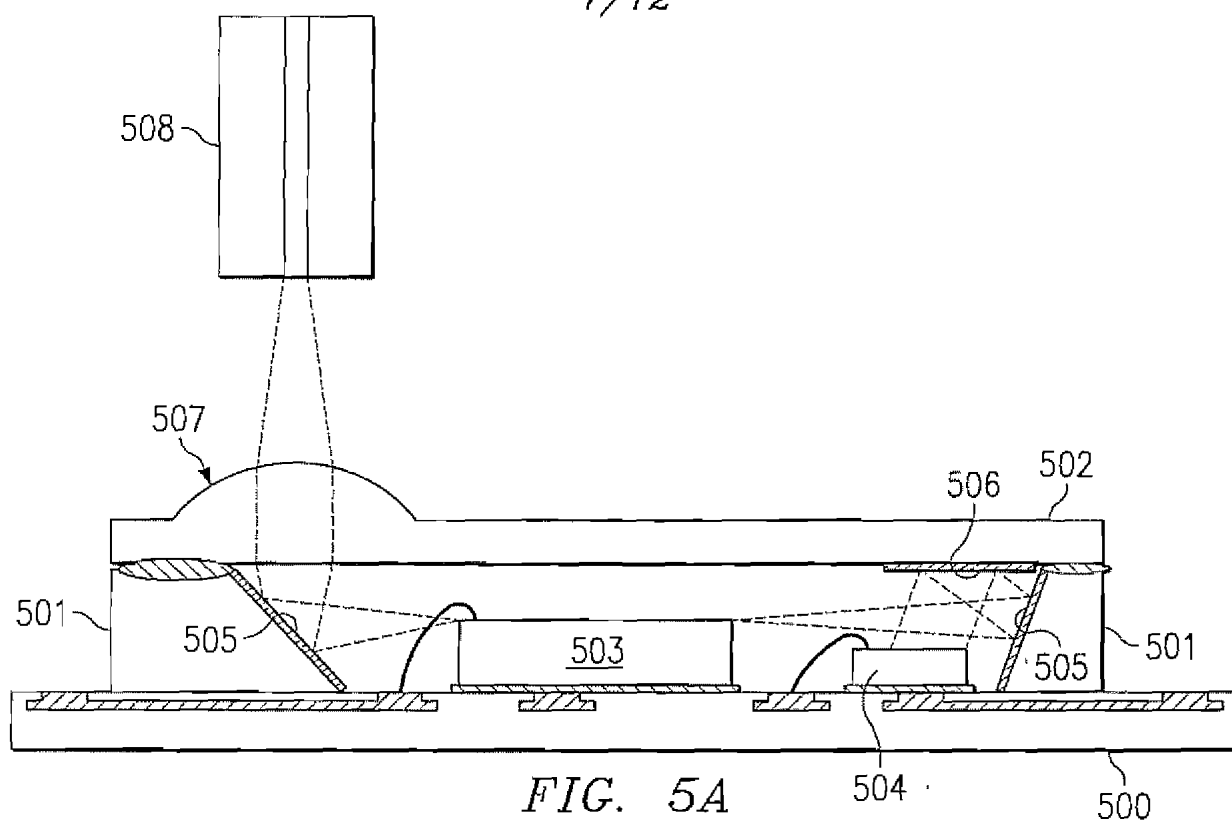


FIG. 4B

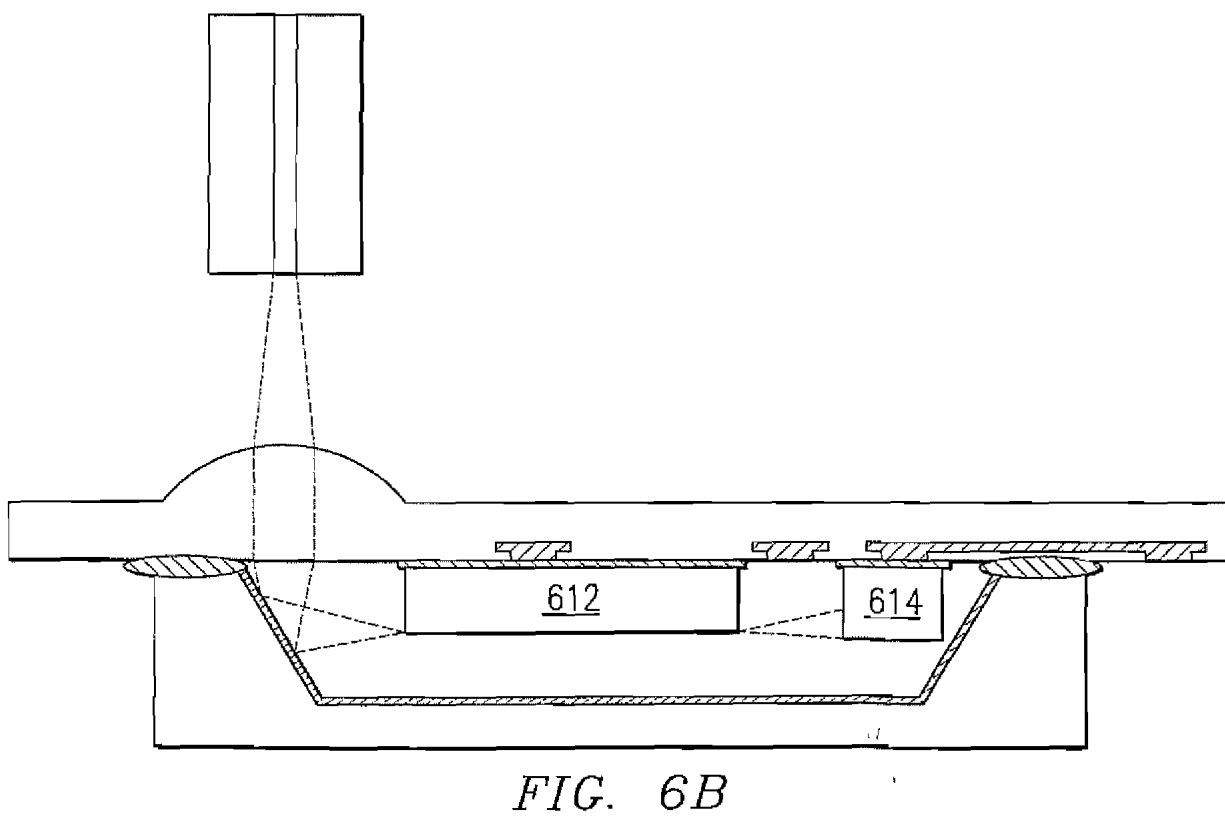
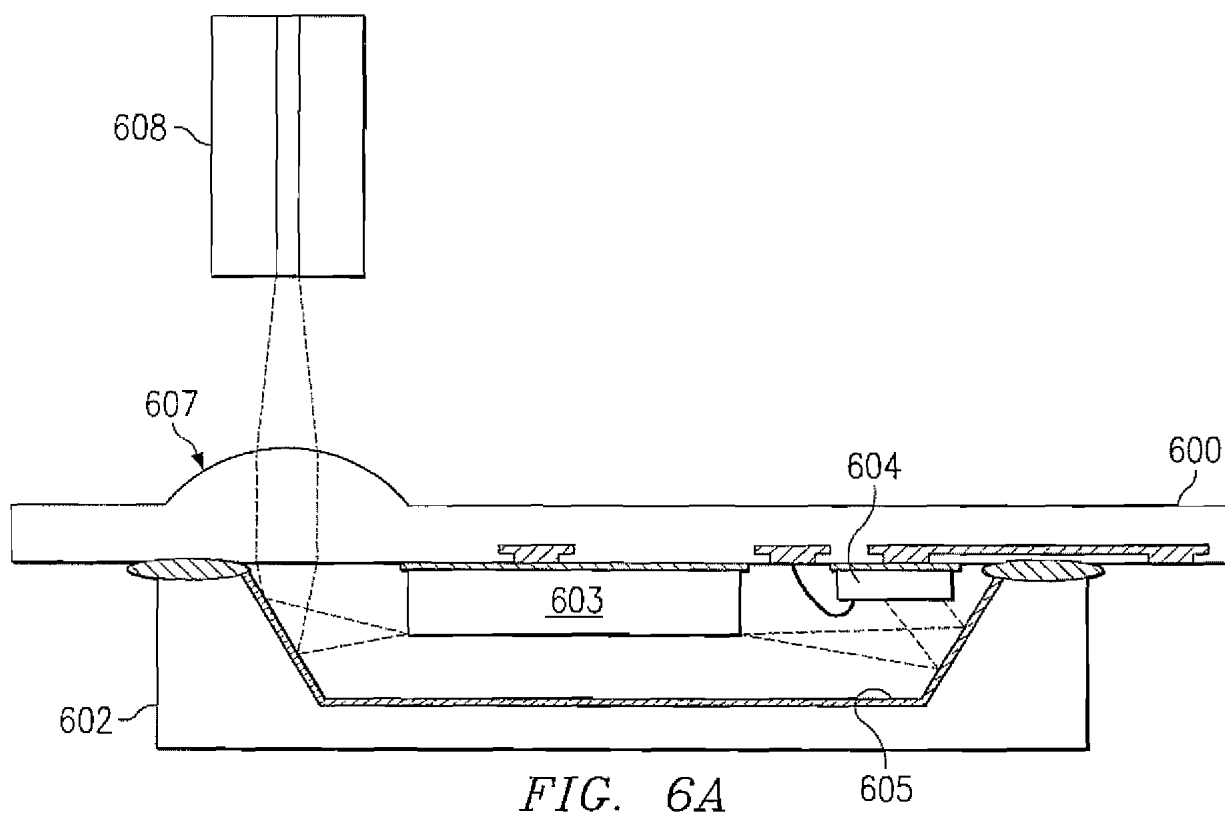
6/12



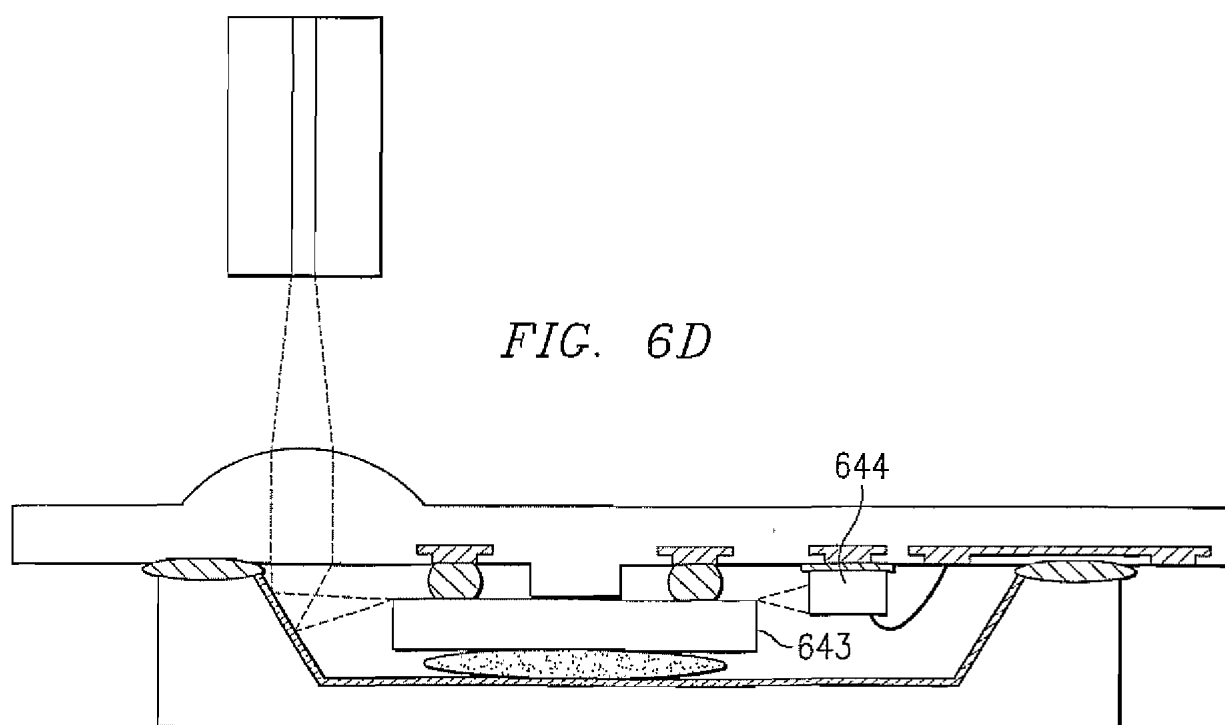
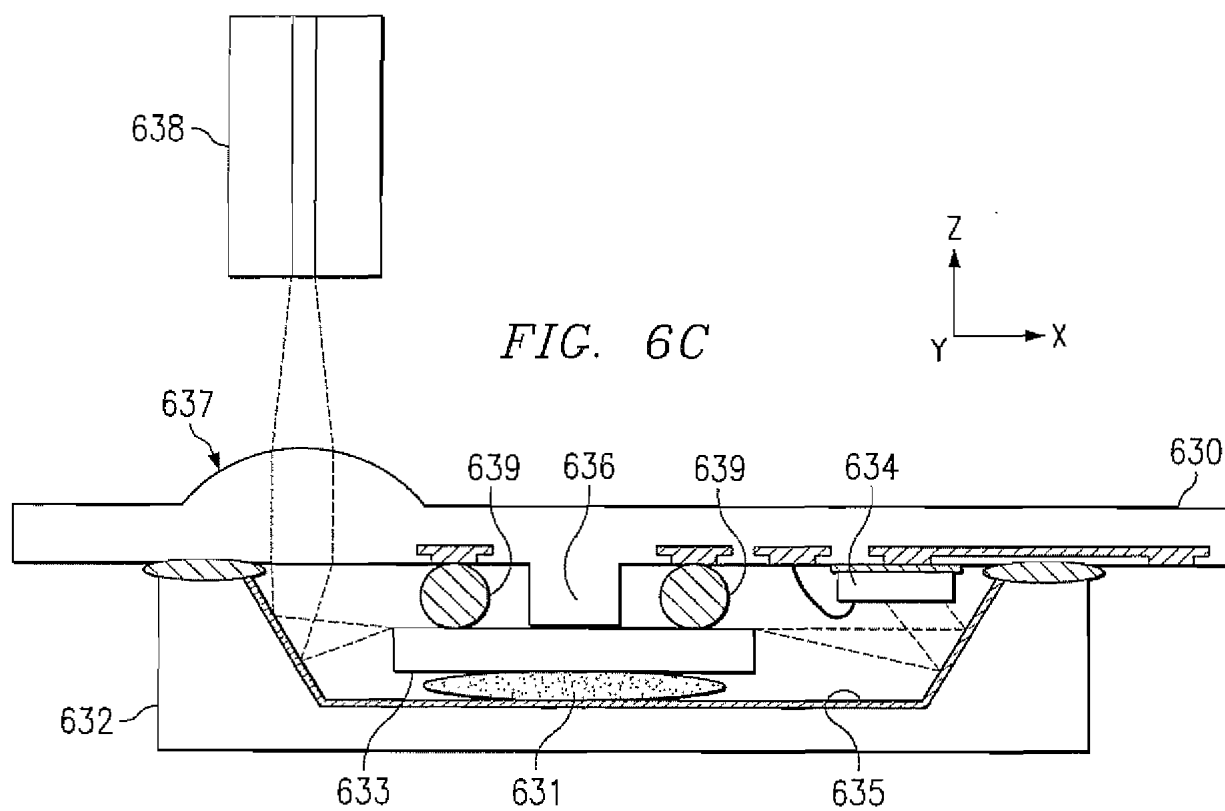
7/12



8/12



9/12



10/12

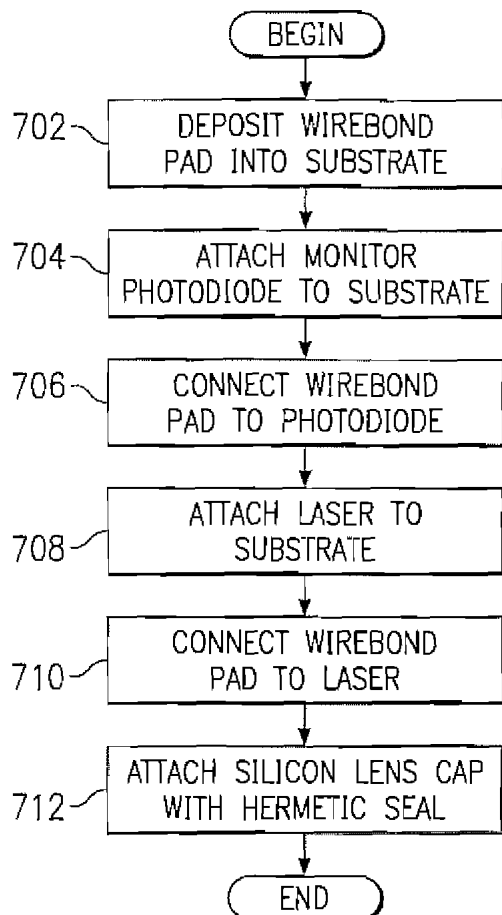


FIG. 7

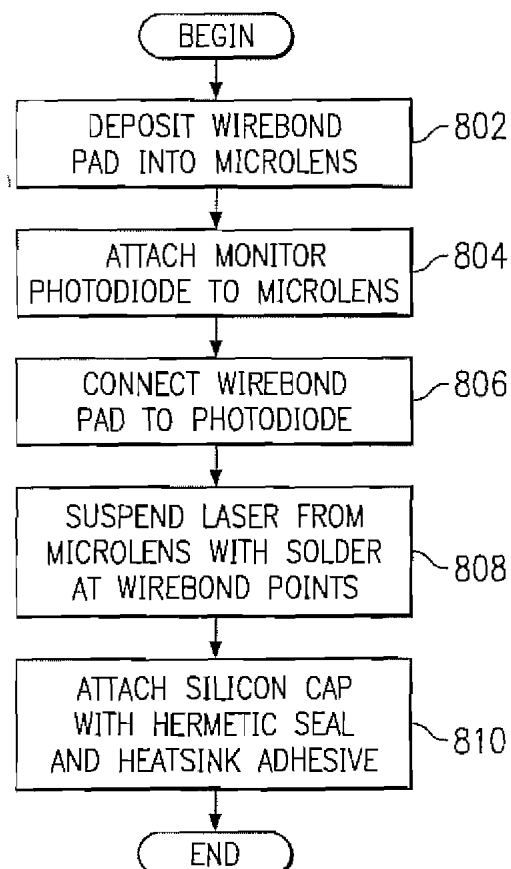
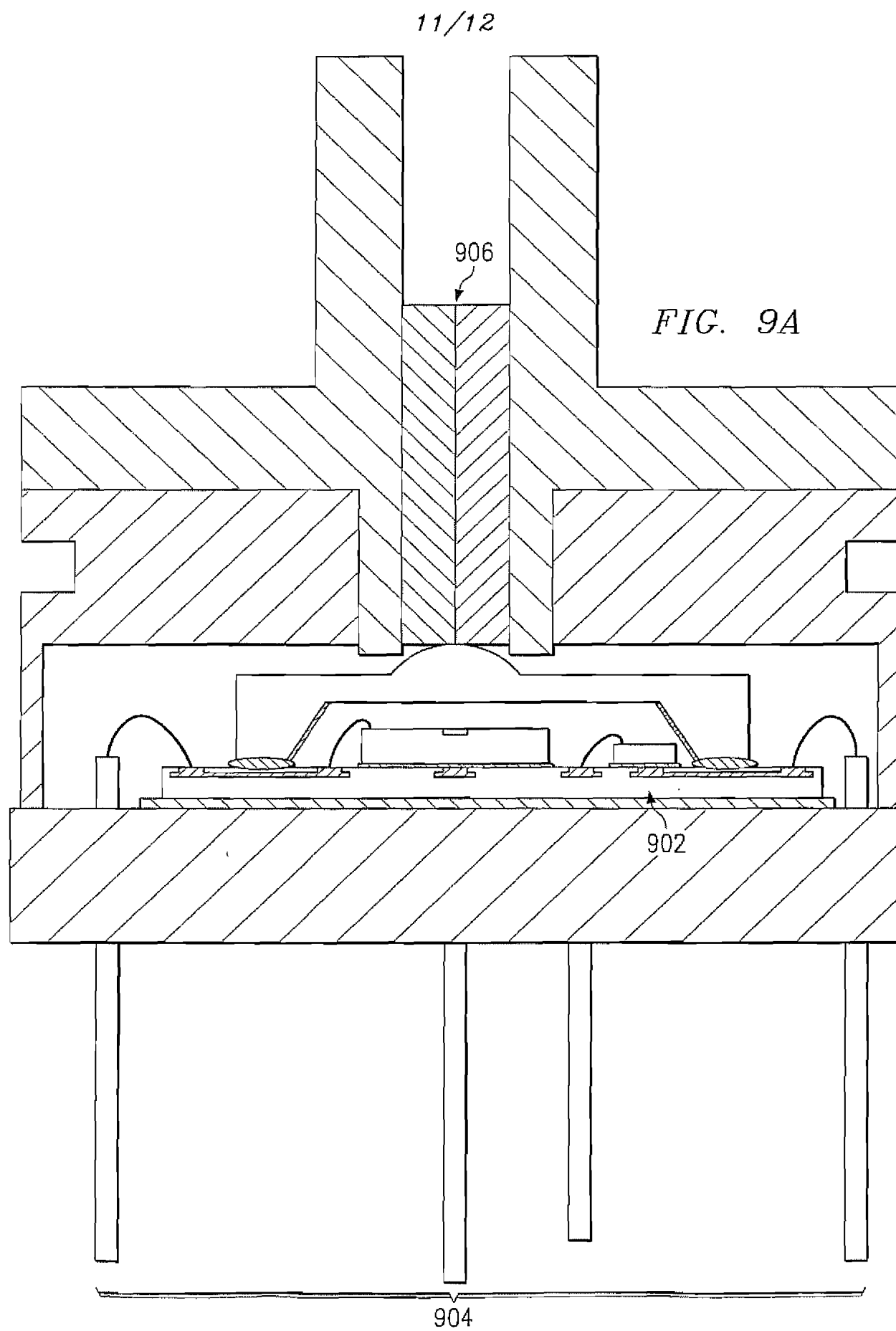
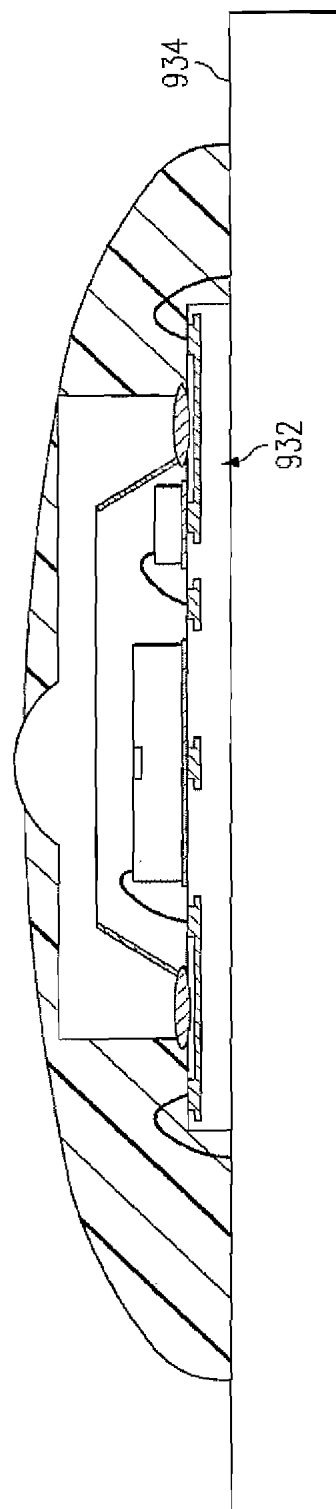
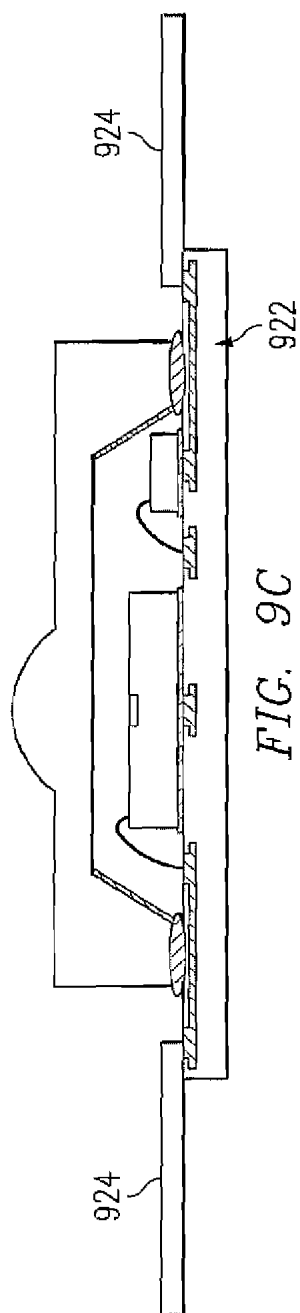
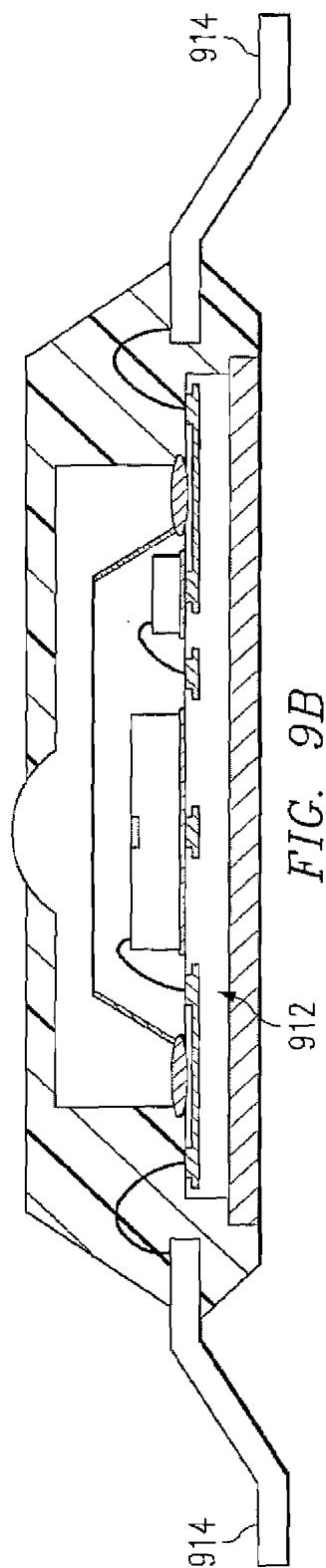


FIG. 8



12/12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/34445

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G01B 11/00; H01S 5/00, 3/08

US CL : 372/43; 438/22; 356/400

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 372/43,92,101,103; 438/22,25,26; 356/400

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,912,872 A (FELDMAN et al.) 15 June 1999 (15.06.1999), see entire document.	1-41

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:		*T*	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier application or patent published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

22 March 2004 (22.03.2004)

Date of mailing of the international search report

30 APR 2004

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US

Commissioner for Patents

P.O. Box 1450

Alexandria, Virginia 22313-1450

Facsimile No. (703) 305-3230

Authorized officer

JOSE DEES

Telephone No. 571-272-1569

INTERNATIONAL SEARCH REPORT

PCT/US03/34445

Continuation of B. FIELDS SEARCHED Item 3:

EPO, JPO, DERWENT USPAT search terms: (second adjl substrates) laser, lens shap\$3, ((photo near detector) photo detector or (photo near diode) or photo diode)